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DOCUMENTS DE TRAVAIL / WORKING PAPERS

No 53-2013

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December 2013

CIRED Working Papers Series

C.I.R.E.D.

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Abstract

In a world of uneven climate policies, concerns about carbon leakage and competitiveness for heavy industries are the main arguments against the implementation of ambitious climate policies. In this paper we investigate a potential competitiveness-driven carbon leakage due to the European Union Emission Trading scheme (EU ETS). We focus on two energy-intensive sectors, cement and steel, and phases I and II of the EU ETS. From a simple analytical model, we derive an equation linking net imports of cement and steel to local and foreign demand along with carbon price. We then econometrically estimate this relation both with ARIMA regression and Prais-Winsten estimation, finding that local and foreign demand are robust drivers of trade flows. We find no significant effect of the carbon price on net imports of steel and cement. We conclude that there is no evidence of carbon leakage in these sectors, at least in the short run.

Keywords: EU ETS, competitiveness, carbon leakage, EITE industries, ARIMA, Prais-Winsten

Fuites de carbone et compétitivité des industries de l'acier et du ciment sous l'EU ETS : beaucoup de bruit pour rien

Résumé

Dans un monde aux politiques climatiques hétérogènes, les préoccupations concernant les fuites de carbone et les pertes de compétitivité des industries lourdes sont les principaux arguments contre l'élaboration de politiques climatiques ambitieuses. Dans cet article nous enquêtons sur d'éventuelles fuites de carbone dues à la perte de compétitivité provoquées par le marché européen du carbone (EU ETS). Nous nous concentrons sur deux secteurs énergie-intensifs, le ciment et l'acier, ainsi que les phases I et II de l'EU ETS. A partir d'un modèle analytique simple, nous dérivons une équation reliant les importations nettes de ciment et d'acier aux demandes locales et internationales ainsi qu'au prix du carbone. Dans un second temps, nous estimons économétriquement cette relation à la fois par une régression ARIMA et par une régression Prais-Winsten. Nous trouvons que les demandes locales et internationales sont des facteurs robustes expliquant les flux commerciaux. Nous ne trouvons en revanche pas d'effet significatif du prix du carbone sur les importations nettes d'acier et de ciment. Nous en concluons qu'il n'y a pas de preuve de fuites de carbone dans ces secteurs, au moins à court terme.

Mots-clés : : EU ETS, compétitivité, fuites de carbone, industries énergie-intensives, ARIMA, Prais-Winsten

Carbon leakage and competitiveness of cement and steel industries under the EU ETS: much ado about nothing

— Working Paper Version —

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Abstract

In a world of uneven climate policies, concerns about carbon leakage and competitiveness for heavy industries are the main arguments against the implementation of ambitious climate policies. In this paper we investigate a potential competitiveness-driven carbon leakage due to the European Union Emission Trading scheme (EU ETS). We focus on two energy-intensive sectors, cement and steel, and phases I and II of the EU ETS. From a simple analytical model, we derive an equation linking net imports of cement and steel to local and foreign demand along with carbon price. We then econometrically estimate this relation both with ARIMA regression and Prais-Winsten estimation, finding that local and foreign demand are robust drivers of trade flows. We find no significant effect of the carbon price on net imports of steel and cement. We conclude that there is no evidence of carbon leakage in these sectors, at least in the short run.

Key-words

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1. Introduction

With international climate negotiations at a standstill, a world of fragmented regional climate policies is emerging (Rayner, 2010) and the perspective of a

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worldwide carbon price has been postponed. The main regional climate pricing experiment so far is the European Union Emissions Trading System (EU ETS), which is presented as the EU flagship climate policy. The EU ETS entered its third phase in 2013, after a first test phase (2005-2007) and a second phase corresponding to the period of compliance for the Kyoto protocol (2008-2012). Different carbon markets have been implemented since then (Hood, 2010; World Bank & Ecofys, 2013) but they remain modest in their ambition. In the two main emitting countries (China and the US), only a minority of states and cities are covered by an ETS. Even in the EU, the current economic downturn has created a massive surplus of allowances, approximating 2 billion tonnes, i.e. one year of emissions (European Commission, 2012), and reduced the CO_2 allowance price to 5 euros vs. around 25 until mid-2008. The European institutions have not yet agreed to reduce the surplus of allowances.

Although there are different reasons for this worldwide lack of ambitious climate policies, among the main ones is the possible threat to the competitiveness of heavy industries and the resulting carbon leakage. The argument goes as follows: carbon-constrained industries may face additional costs vis-à-vis their foreign competitors. This comparative disadvantage may induce immediate losses of market share to the benefit of foreign competitors (operational leakage) or at a longer term location of energy-intensive industries in regions with more favorable climate policies (investment leakage)(Reinaud, 2008b). As a result, emissions would rise in non-constrained countries ("carbon leakage"[1]), weakening or nullifying climate policy efficiency. Moreover, the additional cost generated by the climate policy may reduce the domestic industry's market share, destroy jobs and reduce profits. Such adverse effects are grouped together under the heading of a loss in "competitiveness," a term the popularity of which is inversely proportional to its clarity.

Not only has the threat of carbon leakage reduced the environmental ambition of climate policies (increasing the global cap in the EU ETS), it has pushed public authorities to distribute a large part of allowances for free, generating economic distortions (Meunier et al., 2012) and limiting the use of allowance revenue to reduce preexisting taxes or to produce public goods.

Unfortunately, the existing evidence about the amount of carbon leakage and losses in competitiveness that can be expected from a given climate policy is not conclusive (cf. section 2 below). Among *ex ante* studies, general equilibrium models point to a positive but limited leakage at the aggregate level (typically from 5% to 25%) while for some carbon-intensive sectors like steel or cement, a higher leakage rate is sometimes forecast (Oikonomou et al., 2006; Demailly

[1]Another carbon leakage mechanism is the "international fossil fuel channel": emission reductions go hand in hand with lowering fossil fuel consumption, which drives down fossil fuel prices and in return makes them more attractive for regions with laxer climate policies. Hence all else being equal, they consume more fossil fuels and emit more. Nonetheless, the diffusion to third countries of low-carbon technologies that were favored by the climate policy (climate spillovers) has the opposite effect and induces negative leakage (Gerlagh and Kuik, 2007). We do not address these mechanisms in the present paper.

and Quirion, 2006). Moreover, the few existing *ex post* studies do not afford consistent conclusions.

The present paper aims at filling this gap by econometrically assessing the operational leakage[2] over the first two phases of the EU ETS, in the two most emitting manufacturing industry sectors: cement and steel. The methodology is to econometrically estimate a relationship, obtained via an analytic model, between net imports (imports minus exports) and the carbon price, controlling for other factors that may influence net imports such as economic activity in and outside Europe. Using two different econometric techniques that provide consistent results, we conclude that net imports of cement and steel have been driven by domestic and foreign demand but not by the CO_2 allowance price, falsifying the claim that the ETS has generated leakage, at least in the short run.

The remainder of the article is as follows. Section 2 provides a review of the literature on empirical studies focusing on environmental regulations and trade. Section 3 gives an overview of the industry contexts of the different studied sectors. Section 4 explains the methodology (model and data). Section 5 details the results discussed in section 6.

2. Litterature review

Whereas carbon pricing is relatively new, environmental regulations on local pollutants have a much longer history. For example the Clean Air Act was implemented in the US during the 1970s, well before climate change was on the agenda. Therefore the first studies empirically assessing the impacts of environmental regulations on trade dealt with local pollution issues and tested the pollution haven hypothesis/effect (Kalt, 1988; Tobey, 1990; Grossman and Krueger, 1993; Jaffe et al., 1995). The migration of dirty industries to countries with lower environmental standards (pollution havens) depends both on the environmental regulatory gap and on trade tariffs. In the pollution haven hypothesis (respectively effect), the first (respectively the second) factor is hold constant[3]. The pollution haven hypothesis was a major concern during the negotiations of the North American Free Trade Agreements in the 1990s (Jaffe et al., 1995), but as the decrease in trade tariffs has seemed to slow down, the pollution haven effect has become a more relevant concern (and carbon leakage due the EU ETS would be a “carbon haven effect” (Branger and Quirion, 2013a)).

The prevailing conclusion of the pollution haven literature is that environmental regulations have a small to negligible impact on relocations (Oikonomou et al., 2006). After a first wave of inconclusive works (Eskeland and Harrison,

[2]A distinction can be made between leakage that occurs in the presence of capacity constraints in the short term, termed operational leakage and leakage which occurs in the longer term via the impacts of the EU-ETS on investment policy, termed investment leakage (Climate Strategies, 2013).

[3]For a more elaborated presentation and discussion of these notions, cf. Kuik et al. (2013).

2003), a second generation of studies have statistically demonstrated significant but small pollution haven effects using panels of data and industry or country fixed effects (Levinson and Taylor, 2008). Many reasons have been invoked to explain why the widely believed fear of environmental relocations was not observed. Some have pointed out that environmental regulations are not a main driver of relocations contrary to economic growth in emerging countries (Smarzynska, 2002), or that pollution abatement represents a small fraction of costs compared to other costs or barriers that still favor production in industrialized countries (Oikonomou et al., 2006) such as tariffs, transport costs, labor productivity, volatility in exchange rates and political risk. Others highlight that heavy industries are very capital-intensive and tend to be located in capital-abundant countries, or that their capital intensity makes them less prone to relocate than "footloose" industries (Ederington et al., 2003). Finally, the Porter hypothesis (Porter and Van der Linde, 1995), implying that regulations bring cost-reducing innovations, has also been cited.

The pollution haven literature is mostly related to command-and-control regulations for local pollutants, whereas the EU ETS is a cap-and-trade system for carbon emissions. Some studies evaluate policies which are closer to the EU ETS such as environmental taxation in some European countries. Miltner and Salmons (2009) studied the impact of environmental tax reforms (ETR) on competitiveness indicators for seven European countries and eight sectors and found that, out of 56 cases, the impact of ETR on competitiveness was insignificant in 80% of cases, positive in 4% and negative for only 16% of the cases (Miltner and Salmons 2009). However, energy-intensive sectors benefited from exemptions and lower rates of taxation. Costantini and Mazzanti (2012) used a gravity model to analyse the impact on trade flows of environmental and innovation policies in Europe and revealed a Porter-like mechanism: when the regulatory framework is followed by private innovation, environmental policies seem to foster rather than undermine export dynamics.

The question of carbon leakage was also a relevant issue for the Kyoto protocol. Aichele and Felbermayr (2012) assessed the impact of the Kyoto protocol on CO_2 emissions, CO_2 footprint and CO_2 net imports, using a differences-in-differences approach with the International Criminal Court participation as an instrumental variable for Kyoto ratification. They concluded that the Kyoto protocol has reduced domestic emissions by about 7%, but has not changed the carbon footprint (CO_2 net imports increased by about 14%). Though they do not explicitly formulate it, their results lead to a carbon leakage estimation of about 100%, contrasting with the other empirical studies. However, two caveats are in order. First, China became a member of the WTO in 2002, just when most developed countries were ratifying the protocol. Since most CO_2 net imports are due to trade with China, the rise in net imports may well be due to China World Trade Organization (WTO) membership rather than to the Kyoto protocol. Second, apart from those covered by the EU ETS, countries with a Kyoto target have not adopted significant policies to reduce emissions in the manufacturing industry. Hence, if Kyoto had caused leakage (through the competitiveness channel), it should show up on the CO_2 net imports of countries covered by the EU ETS rather than on CO_2 net imports of countries covered by a Kyoto target. However, when the authors include both EU membership and the existence of a Kyoto target in the regression, they report that EU membership does not increase CO_2 imports.

Some papers use econometric models to empirically investigate the impact of climate policies on heavy industries *ex ante*, using energy prices as a proxy. Gerlagh and Mathys (2011) studied the links between energy abundance and trade in 14 countries in Europe, Asia and America. They found that energy is a major driver for sector location through specialisation, but they do not quantify relocations under uneven carbon policies. Aldy and Pizer (2011) focused on the US but used a richer sectoral disaggregation. The authors concluded that a \$15 price of CO_2 would not significantly affect the US manufacturing industry as a whole, but that some sectors would be harder hit with a decrease of about 3% in their production.

The EU ETS has constituted a subject of research for a body of empirical studies on different topics: abatement estimation (Ellerman and Buchner, 2008; Delarue et al., 2008), impact of investment and innovation (Calel and Dechezleprêtre, 2012; Martin et al., 2012), distributional effects (Sijm et al. 2006, de Bruyn et al. 2010, Alexeeva-Talebi 2011), determinants of the CO_2 price (Alberola et al., 2008; Mansanet-Bataller et al., 2011; Hintermann, 2010), but only a limited number of ex post studies have investigated carbon leakage in relation to the EU ETS.

So far, these studies have not revealed any statistical evidence of carbon leakage and losses in competitiveness for heavy industries in the EU ETS. Zachman et al. (2011), using firm level panel data and a matching procedure between regulated and unregulated firms, found no evidence that the ETS affected companies profits. Studying the impact of carbon price on trade flows, several studies found no evidence of competitiveness-driven operational leakage for the different sectors at risk of the EU ETS: aluminium (Reinaud, 2008a; Sartor, 2013; Ellerman et al., 2010; Quirion, 2011), oil refining (Lacombe, 2008), cement and steel (Ellerman et al., 2010; Quirion, 2011). These results contrast with *ex ante* studies, generally with CGE models (Böhringer et al., 2012) but also with sectoral partial equilibrium models (Monjon and Quirion 2011) that forecast an aggregated carbon leakage ratio in a range of 5% to 25% (Branger and Quirion, 2013b) and even more with studies devoted to the cement and steel sectors, which conclude to a leakage ratio in a range of 20% to 60%.

Our work goes beyond the above-mentioned studies on several points. First, more data is available as the EU ETS has entered its third phase after eight years of functioning. Second, we introduce a new variable as a proxy for demand outside the EU, which improves the explanatory power of the econometric model. Third, the estimated equations are based on a structural economic model. Finally, we use several time-series regression techniques, which improves the robustness of the results.

3. Industry contexts

Cement and steel are both heavy industries affected by the EU ETS. They are the two largest CO_2 emitters among European manufacturing sectors, representing 10% and 9% respectively of the allowance allocations in the EU ETS (Trotignon, 2012). However they rank differently along the two dimensions generally retained for assessing whether a sector is at risk of carbon leakage, i.e. carbon intensity and openness to international trade (Hourcade et al., 2007; Juergens et al., 2013). Cement is very carbon-intensive but only moderately open to international trade while steel features lower carbon intensity but higher trade openness.

3.1. Cement

Calcination of limestone and burning of fossil fuel (mainly coal and petroleum coke) to heat material at high temperature make the cement manufacturing process very carbon-intensive (around 650kg of CO_2 per tonne[4]). Cement production embodies 5% of worldwide emissions (IEA, 2009).

The raw material of cement, limestone, is present in abundant quantities all over the world. Moreover, the value per tonne of cement is relatively low. Because of these two features, cement is produced in virtually all countries around the world and is only moderately traded internationally (only 3.8% of cement was traded internationally in 2011 (ICR, 2012)). China represents the lion's share of cement consumption and production around the world, due to the large scale developments and infrastructure build-up projects that the Chinese government is undertaking. In 2011, 57% of the 3.6 billion tonnes of cement were produced in China, and the second country producer, India, was far behind with 6% of world production (ICR, 2012).

Cement is a sector where international competition is low (Selim and Salem, 2010). Because of low value per tonne and market concentration, important price differences remain even within Europe (Ponssard and Walker, 2008). Prices are higher and producers have more market power inland than near the coasts because transportation costs are much lower by sea than by road.

Clinker is the major raw material for cement (Portland cement, the most common type of cement is made up of 95% of clinker). Its production accounts for most of the CO_2 emitted in the manufacturing process, and it can be transported more easily. Therefore in the cement sector, carbon leakage is more likely to happen through clinker trade than through cement trade.

3.2. Steel

Steel is produced either from iron ore and coal using the Blast Furnace - Basic Oxygen Furnaces (BOF) route, for around 70% of world production, or from steel scrap in Electric Arc Furnaces (EAF), for 29% of world production in

[4]source: WBCSD, Getting the Numbers Right database, accessed December 2013. http://wbcsdcement.org/index.php/key-issues/climate-protection/gnr-database

2011 (WSA, 2012). The BOF process is roughly five times more carbon-intensive than the EAF but the share of the latter is limited by scrap availability. Steel is very carbon-intensive and accounts for 6% of worldwide emissions (Carbon Trust, 2011b).

Like cement but to a lesser extent, China embodies most of the world steel consumption and production: 45% of the 1,518 million tonnes of 2011 world production (followed by the EU with 12%). Steel has a much higher value-added per tonne than cement (roughly ten times more) and is thus more widely traded. In 2011, 31% of finished steel products were internationally traded (WSA, 2012).

Steel prices, are more homogenous than cement prices and steel futures are sold even on the London Metal Stock exchange. International competition is higher in steel than in cement (Ecorys, 2008).

Table 1: Summary characteristics of the two sectors. Sources: (WCA, 2011; WSA, 2012; ICR, 2012; CWR, 2011; Carbon Trust, 2011a; Holmes et al., 2011)

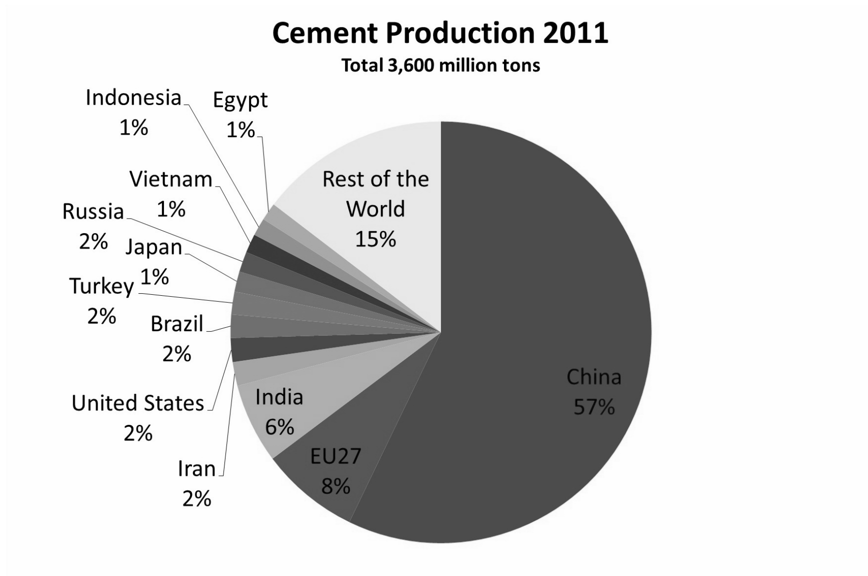
	Cement	Steel
% of World GHG emissions	5%	6%
Carbon intensity[1]	0.6-0.8	2-4 (BOF)
		0.2-0.9 (EAF)
World Production[2]	3,600	1,514
Top Producer (2011)	China (57%)	China (47%)
Other Main Producers	EU27, India	EU27, Japan, US
Bulkiness ($/tonne)	45-150	500-800
Trade intensity[3]	3.8% (2011)	31.4% (2011)
Market concentration[4]	25%	27.5%
Largest Company	Lafarge	ArcelorMittal
(2011 - % production)	5%	6.4%
International competition	Low	Moderate

[1] Tonnes of CO_2 per tonne of output
[2] 2011. Million tonnes
[3] % of world production traded internationally
[4] Top 10 companies' share in production

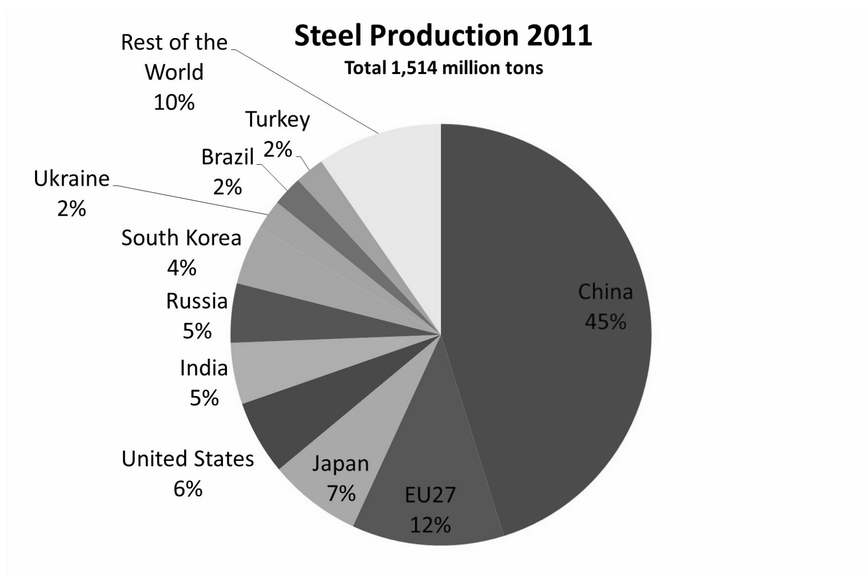
4. Methodology and data

Our goal is to study the impact of carbon price on *competitiveness-driven operational leakage*, at a geographically aggregated level (European Union versus the rest of the world) for two sectors "deemed to be exposed at risk of carbon leakage:" cement and steel.

If carbon leakage occurs, it is through the trade of carbon intensive products. An indicator of carbon leakage is then a change in international trade flows



(a) Cement



(b) Steel

Figure 1: World production of cement and steel (sources : (WSA, 2012; ICR, 2012)

of carbon-constraint products (measured by net imports, i.e. imports minus exports).

4.1. Analytical model

We build the simplest possible model capable of featuring carbon leakage. Industries of two regions, e (Europe) and r (rest of the world) are in perfect competition. Therefore the price in each region is equal to the marginal cost. This perfect competition may seem a bold hypothesis, especially for the cement sector, which, in at least some countries, is rather concentrated. However, introducing imperfect competition would significantly complicate the model without necessarily bringing new insights. For example, Cournot competition may reduce the sensitivity of net imports to a price asymmetry and thus leakage, but the results would then become very sensitive to the shape of the demand curve (Demailly and Quirion, 2008).

There is no product differentiation. This assumption, like perfect competition, is chosen for the sake of simplicity. Moreover, we neglect transportation costs for two reasons. First, their introduction would hinder the ability to produce a simple equation to estimate. Second, the estimation of the model with transport costs causes problems of endogeneity (net imports of cement and steel are drivers of shipping costs). Finally, we assume fixed demand, i.e. world demand is not dependent on world price p.

We suppose production costs are quadratic, so marginal costs are linear. The extra cost due to the climate policy (only in region e) is strictly proportional to production. The marginal cost of production, which equals the world price in both regions, is then

$$p = ci_e + CO_{2Cost} + cs_e q_e \tag{1}$$

in Europe and

$$p = ci_r + cs_r q_r \tag{2}$$

in the rest of the world, where q_e and q_r are the *productions* in regions e and r, CO_{2Cost} the carbon cost times specific emissions[5] plus the abatement cost per unit produced, if any, ci_e and cs_e (respectively ci_r and cs_r) parameters of the production cost in Europe (respectively the rest of the world).

Trade occurs between the two regions, and we note q_m the net imports from region r to region e. The *demands* in regions e and r are :

[5]Hence we assume that firms maximise profit taking the full opportunity cost of CO_2 allowances into consideration. If, on the opposite, firms take only the cost of the CO_2 allowances they must buy into account, no impact can be expected since cement and steel benefited from a large over-allocation in the period considered.

$$d_e = q_e + q_m \quad (3)$$

$$d_r = q_r - q_m \quad (4)$$

$cs_e \times(3)$ - $cs_r \times(4)$ leads to:

$$(cs_e + cs_r)q_m = cs_e d_e - cs_r d_r - cs_e q_e + cs_r q_r \quad (5)$$

Using (1) and (2) to substitute $cs_e q_e$ and $cs_r q_r$ respectively, and dividing by $(cs_e + cs_r)$ we finally obtain:

$$q_m = \frac{ci_e - ci_r}{cs_e + cs_r} + \frac{1}{cs_e + cs_r} CO_{2Cost} + \frac{cs_e}{cs_e + cs_r} d_e + \frac{-cs_r}{cs_e + cs_r} d_r \quad (6)$$

4.2. Estimated equation

A reformulation of (6) is:

$$\begin{aligned} NImp_{Cement,t} =& \alpha_C CO_2price_{t-3} + \beta_C Cons_{EU,t-3} \\ & + \gamma_C Ind_{BRICS,t-3} + const_C + \varepsilon_{C,t} \end{aligned} \quad (7)$$

for cement, and

$$\begin{aligned} NImp_{Steel,t} =& \alpha_S CO_2price_{t-3} + \beta_S Ind_{EU,t-3} \\ & + \gamma_S Ind_{BRICS,t-3} + const_S + \varepsilon_{S,t} \end{aligned} \quad (8)$$

for steel, where α_C, β_C, γ_C, α_S, β_S, and γ_S are the coefficients to be estimated while $\varepsilon_{C,t}$ and $\varepsilon_{S,t}$ are the residuals, which we assume to be IID, that is later to be tested. The variables are (the source of the data will be detailed in 4.4):

- *Net imports* ($NImp$), or imports minus exports, for each of the two sectors, between the EU27 and the rest of the World. This is the predicated variable, and a proxy for operational leakage. The choice of the geographical delimitation (EU27) is not trivial. Indeed in 2007, the two new member states, Bulgaria and Romania, joined the EU ETS. One year later, the EU ETS welcomed Norway, Iceland and Liechtenstein, countries not in the European Union. As the purpose of this article is to study the impact of the EU ETS on competitiveness and leakage, another option was to consider an EU ETS geographical coverage changing over time. This would have posed econometric problems since it would have introduced shocks in the time series. Since these five countries do not produce a significant share of European production, we judge that it was a preferable option not to take these changes into account.

- *CO_2 price*. This is the main regression variable. In the presence of operational leakage due to losses in competitiveness, a positive relationship is expected. Indeed, a high carbon price would induce an increase in the production cost of European products, a loss of market share of European industries vis-à-vis their foreign competitors, and an increase in net imports. We consider the EUA future price (one year ahead) for two reasons. First, contrary to the spot price, it did not collapse in 2007, which would have biased the econometrical estimation (Creti et al. (2012); Bredin and Muckley (2011); Conrad et al. (2012) use the future price for the same reason). Second, future prices are available from 2004 (contrary to 2005 for spot prices), which adds one more year (or twelve more points) to the time series and thus makes the econometric estimation more robust.

- *EU industrial output*, *EU construction index* and *BRICS industrial output* (Ind_{EU}, $Cons_{EU}$ and Ind_{BRICS}). The industrial output is a proxy for the industrial economic activity and therefore the demand side (either domestic or foreign). For cement, we used the European construction index instead of the European industrial output to proxy the demand as construction is the main outlet for cement. We did not find a satisfactory construction index for the BRICS so we used the industrial output for both steel and cement. An increase in local demand is expected to increase the demand of imports and reduce production capacities available for exports. We therefore expect a positive (respectively negative) relation for the European (respectively BRICS) industrial output. We chose to focus on BRICS countries instead of taking an aggregated industrial production index for the rest of the world because to our knowledge such a global index does not exist. Moreover, BRICS countries are the engine of global economic growth: from 8% in 1999, they represented in 2011 20% or the world's GDP. The consumption of cement and steel in BRICS countries (and especially in China) has soared over the last decade. They are not the major destination of EU27 steel exports; however, they are the origin of a noticeable part of EU27 cement and steel imports (China and Russia for steel, China for cement especially between 2005 and 2008) as well as cement exports recently (Russia and Brazil).

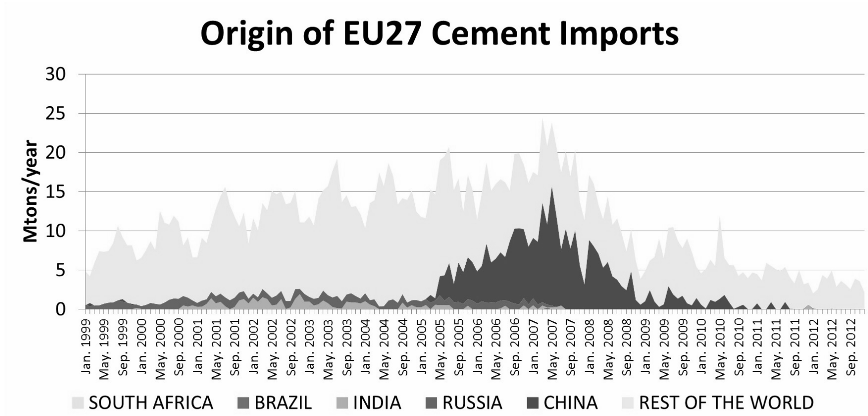
To take into account the fact that the potential effect of carbon price on net imports is not instantaneous but necessitates some time (time between production and sale), we introduce a lag in the dependant variables. We select a lag of three months since it brings the best fit[6], as measured by the usual indicators[7]

4.3. Econometrical techniques

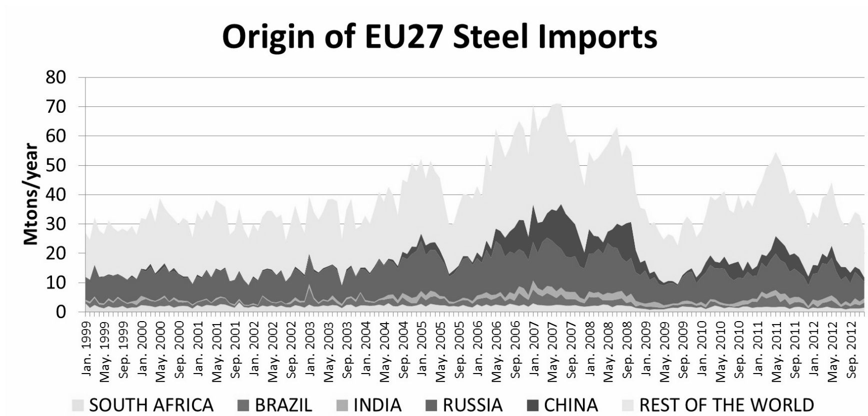
Two aspects are potential barriers to the validity of econometric estimations: endogeneity and the issue of autocorrelation of residuals, since we work on time

[6]The results are very robust to a change in the lag (from 1 to 5 months), except for cement in the ARIMA regressions. These results are available upon request

[7]R^2 for the Prais-Winsten regression and the AIC for the ARIMA regression



(a) Cement



(b) Steel

Figure 2: Origin of EU27 imports

series data.

First let us consider the thorny issue of endogeneity. It is necessary that variables aimed at explaining the variations of net imports be truly exogenous to validate our econometrical modeling. Such would not be the case if the net imports of cement or steel impacted these explanatory variables. Cement and steel sectors each stand for less than 10% of the covered emissions in the EU ETS. As most of the production is consumed within the EU, variations in net imports induce much less important production variations. It is therefore highly likely that variations in net imports do not affect the carbon price.

Another source of endogeneity would be that an omitted variable would impact both our main regression variable, the CO_2 price, and the predicated variable. Among the price determinants of the carbon price one can cite the economic activity (which is in the regression with Ind_{EU} or $Cons_{EU}$), political decisions, energy prices (mainly coal and gas[8]) and unexpected weather variations[9] (Alberola et al., 2008; Hintermann, 2010). It seems unlikely that political decisions related to the EU ETS and unexpected weather variations would impact net imports of cement and steel otherwise than potentially through carbon price. Energy prices affect production costs but we suppose that the effect is the same for production outside Europe because prices are determined on a global scale for coal and petcoke, the main energy carriers used for cement and steel production. Therefore, the effect would be compensated between imports and exports.

A simple linear regression would give spurious results because of a strong autocorrelation of error terms, as in many time series data. As the Augmented Dickey-Fuller test shows, all time series are I(1), as we cannot reject the hypothesis of a unit root for the time series but we can for their first difference (see results in annex). To treat the question of autocorrelation of residuals, we use two different methods. The first one is the Prais-Winsten estimation, which is an improvement of the Cochrane-Orchutt algorithm[10]. The second one is the classically used model in time series analysis, the ARIMA(p,1,q) model. We identified the ARIMA(p,1,q) process that suits each dependent variable by following the Box and Jenkins methodology and found ARIMA(5,1,3) and ARIMA(6,1,4) for cement and steel respectively. We used the Ljung-Box-Pierce

[8]An increase in coal price (resp. gas price) makes this source of energy less attractive for electricity production. Therefore the emissions are lower (resp. higher) than expected and the carbon price decreases (resp. increases)

[9]Because unexpected cold waves and heat waves generally induce the use of very carbon intensive power plants

[10]In a series of recent articles, McCallum (2010), Kolev (2011) and Zhang (2013) have concluded that most so-called "spurious regression" problems are solved by applying the traditional methods of autocorrelation correction, like the iterated Cochrane-Orchutt procedure (Cochrane and Orcutt, 1949). However, other authors, including Martínez-Rivera and Ventosa-Santaulària (2012), Sollis (2011) and Ventosa-Santaularia (2012), have argued that these procedures do not always avoid spurious regressions and propose to pre-test the data and first-differentiating them if they appear to be I(1). Hence we apply both methods in this paper.

test (which will be explained in further detail in part 5.2) to evaluate the results.

Longer time series give more robust estimations, but including the carbon price for the period 1999-2012 would give spurious results, since there is a break in the time series (this variable is at zero during 1999-2003, then positive). We performed the first regression to have a most robust estimation of net imports depending on local and foreign demand. Then we undertook a second regression for the period 2004-2012 including the carbon price. Comparing the results allows assessing whether the previous estimation is robust in time and examining the effect of adding a carbon price.

4.4. Data

All the data are *monthly* from January 1999 to December 2012 (168 points), except for the carbon prices taken from January 2004 to December 2012 (108 points).

- *Net imports of cement and steel of EU27.* Eurostat international trade database[11]. For cement we take clinker into account, as this semi-finished product is more prone to carbon leakage. For steel, we consider iron and steel in the broad sense, which includes pig iron and semi-finished steel products. The original values in 100kg are converted into Mt/year (with the formula 1Mt/year=833333.3 100kg/month).

- *CO_2 price.* Carbon prices are taken from Tendances Carbone edited by CDC Climat[12].

- *EU industrial output* and *EU construction index.* Eurostat database[13]. They are both normalized at 2005=100.

- *BRICS industrial output.* Several steps were necessary to compute this index. First, for Brazil, Russia, India and South Africa, the productions in total manufacturing (normalized at 2005=100), were available on the Federal Reserve of Saint Louis Economic Research website[14] derived from the OECD Main Economic Indicators database. China's published industrial statistics are far from being open and the scattered available data are confusing (with changes in variables, in coverage, in measurement, and in presentation). Holtz (2013) reviewed the available official data and constructed a monthly industrial output series. Monthly industrial output (economy-wide constant price) was taken from this paper for the years 1999 to 2011, and extended for the year 2012 thanks to online data[15] giving

[11]EU27 Trade Since 1988 by HS2, 4, 6 and CN8 dataset (extracted in April 2013). The respective codes for cement and steel are 2523 (cement, including clinker, whether or not coloured) and 72 (iron and steel)

[12]http://www.cdcclimat.com/-Publications-8-.html

[13]Production in industry and Production in construction- monthly data (extracted in April 2013)

[14]http://research.stlouisfed.org/fred2/

[15]http://www.tradingeconomics.com/china/industrial-production

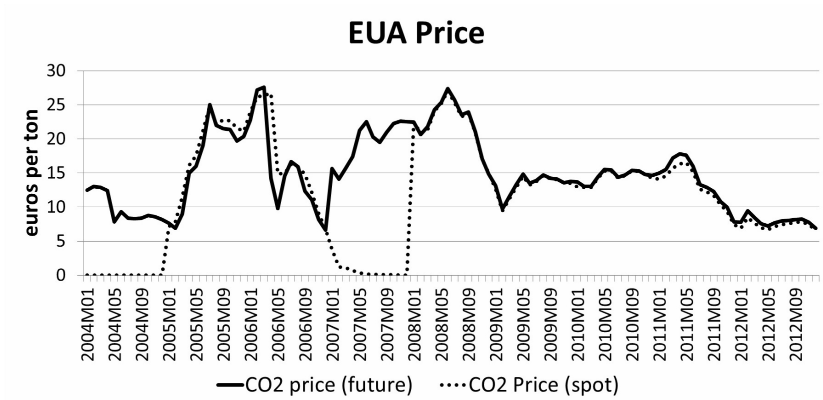


Figure 3: EUA price

an annual increase rate of industrial output every month. The obtained data are cyclical: the industrial production is at its highest in December and at its lowest in January and February. We regress the log of this industrial output over time and monthly dummies to estimate seasonal factors, then we withdraw these factors from the original data to obtain a seasonally adjusted Chinese industrial output (which we normalize at 2005=100). Finally, the BRICS industrial output is the weighted mean of national industrial outputs (the weights are the 2005 GDP[16]).

5. Results

5.1. Descriptive statistics

Table 2: Summary statistics of the regression variables

Variable	Obs	Mean	Std dev	Min	(date)	Max	(date)
$NImp_{Cement}$	168	0.19	7.34	-17.95	Jun 2012	19.57	Mar 2007
$NImp_{Steel}$	168	-0.35	13.07	-26.56	Aug 2012	35.62	Jan 2007
CO_2price	108	14.89	5.55	6.60	Dec 2012	27.60	Mar 2006
$Cons_{EU}$	168	97.10	5.83	84.16	Feb 2012	110.44	Feb 2008
Ind_{EU}	168	99.86	5.52	89.67	Apr 2009	113.10	Jan 2008
Ind_{BRICS}	168	113.38	35.51	63.18	Feb 1999	178.46	Dec 2012

Obs=Observations Std dev=Standard deviation

Future carbon prices (see Figure 3) existed in January 2004, one year before the beginning of the EU ETS in January 2005, and oscillated at around 8 euros.

[16]United Nations (http://unstats.un.org/unsd/snaama/dnltransfer.asp?fID=2)

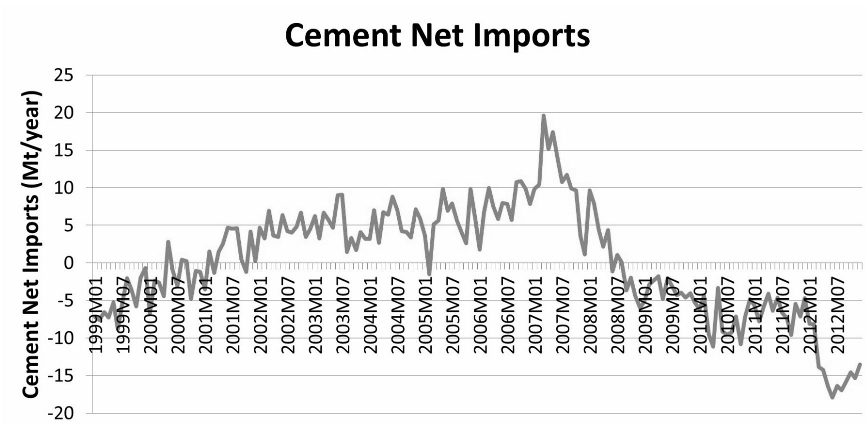
They then increased rapidly during the beginning of phase I of the EU ETS to fluctuate at around 25 euros between June 2005 and April 2006. The release of 2005 verified emissions suggested that most of the installations had emitted less than their number of allowances. As no banking was allowed between phase I (2005-2007) and phase II (2008-2012), this surplus of allowances led to a crash of the carbon spot price, and a severe decrease in the future price. During the second phase, the EUA price rose as during the first phase to exceed 20 euros, then fell under 10 euros as it appeared that the economic crisis was going to noticeably reduce the demand for allowances. For two years from June 2009 to June 2011, the carbon price was stable between 13 and 16 euros. The carbon price fell under 5 euros six months later for several reasons (duration of the economic crisis in Europe due to the sovereign debt crisis, interaction with other energy efficiency or renewable climate policies reducing the demand, increasing of allowances), and remained at this price for the year 2012.

The net imports of cement (see Figure 4) increasingly rose from 1999 to reach a peak in March 2007 at 20 Mtonnes per year then continuously fell with a recent severe collapse at the beginning of 2012. In 2009, the EU became a net exporter of cement whereas it was a net importer from 2001 to 2007.

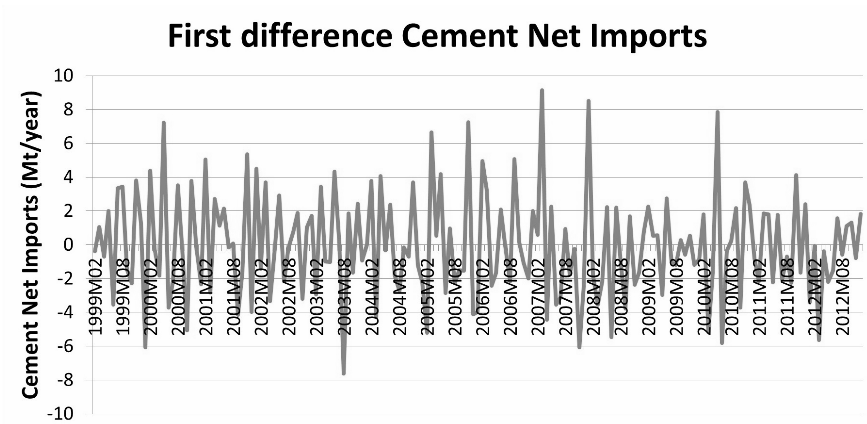
The steel net imports (see Figure 5) oscillated at around zero from 1999 to 2005, then the EU became a net importer from 2005 to 2008. Net imports peaked in summer 2007, with 33 Mtonnes per year then collapsed the same year. After a rebound up to 20 Mtonnes per year, the steel net imports fell during the economic crisis. Since then, with the exception of the beginning of 2011, the EU has been a net exporter of steel.

At first sight, cement and steel net imports and the carbon price do not seem highly correlated. The two high carbon price periods (2005-2006 and 2008) most of the time did not coincide with high net imports. On the contrary, for these two products, net imports reached their peak in 2007, while the spot carbon price was very low. Still, it was also a time of intense industrial activity in Europe, a parameter that is taken into account in the regression.

The EU industrial output increased slightly from 1999 to 2008, then collapsed during the economic recession (by about 20% in six months to go back to its level 10 years before). After a rebound until 2011 without reaching its pre-crisis level, it fell a second time. The EU construction index is very similar, except it plummeted less sharply during the financial crisis, though it never recovered. The BRICS industrial output presents some differences. First, contrary to the EU industrial output, which did not change significantly between 1999 and 2012, the BRICS industrial output almost tripled during the same period. Also hit by the global financial crisis, it took only a year to get back to its pre-crisis level. Contrary to its European equivalent, it has grown steadily since then. Year 2011 marked a discrepancy in industrial activities between Europe and the BRICS. Whereas the EU was getting bogged down in a deep economic and industrial recession, the BRICS manufacturing industries were flourishing. For econometric considerations, as the two series before 2011 were much better correlated, this outcome is also of interest to prevent an identification problem.

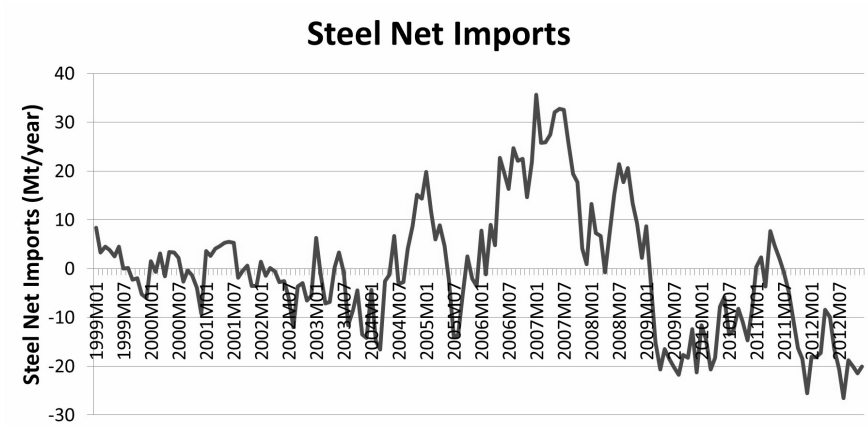


(a) Cement

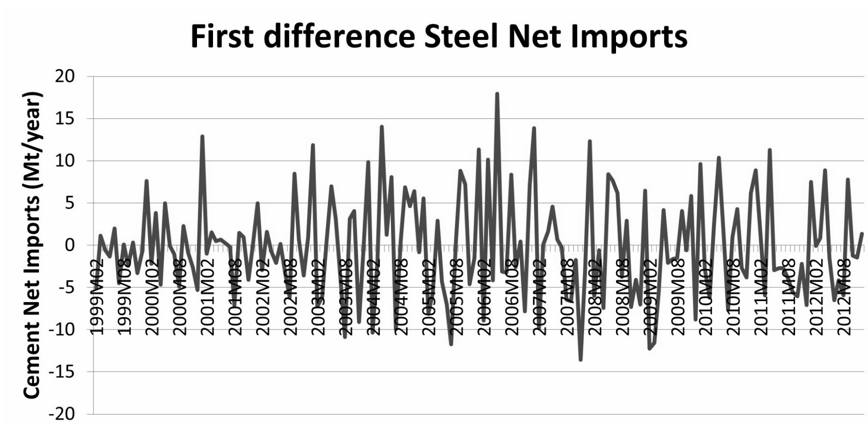


(b) Cement (first difference)

Figure 4: Net Imports (Imports minus Exports) of Cement



(a) Steel



(b) Steel (first difference)

Figure 5: Net Imports (Imports minus Exports) of Steel

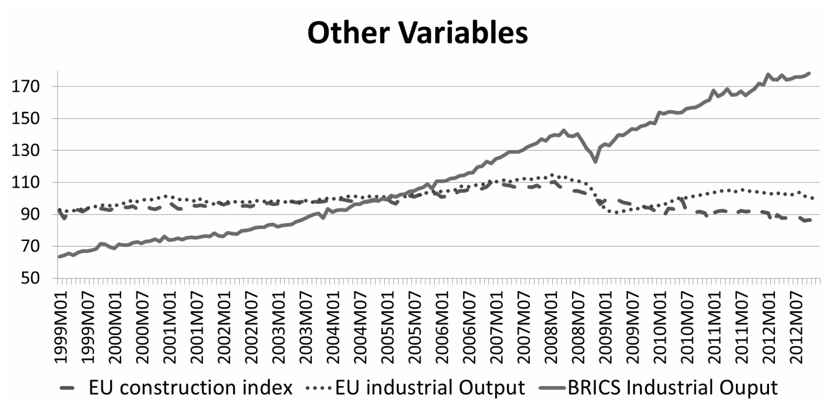


Figure 6: Other regression variables

5.2. Regression results

The results are visible in tables 3 and 5 for the ARIMA estimations[17], and in tables 4 and 6 for the Prais-Winsten estimations. We recall that for each sector, two estimations are performed, one without the carbon price, for the period 1999-2012, and one with the carbon price for the period 2004-2012 (see section 4.3). Comparing the results with the second regression makes it possible to examine the impact of adding a carbon price.

For the ARIMA regressions, the quality of the regressions is assessed with several diagnostic tests: the log-likelihood, the Schwartz and Akaike information criterions (SIC and AIC), and the Ljung-Box-Pierce statistic (Q test) with a maximum number of lags of 40. The null hypothesis in this test is that the residuals are not autocorrelated, so the observed correlations are just a result of randomness. The critical region for rejection of the hypothesis of randomness is when Q is higher than the α-quantile of a chi-squared distribution. If we take $\alpha = 5\%$, the model is validated if "Prob>chi(40)">5%, though a higher p-value indicates that the model is a better fit. For the Prais-Winsten estimations, we give the value of R^2 and the Durbin-Watson test (which is close to 2 if there is no autocorrelation in the residuals) before and after transformation.

In all the ARIMA regressions, the Q-tests validate that the residuals are white noise and in all the Prais-Winsten regressions, the Durbin-Watson tests assure that the residuals are not autocorrelated.

For cement, in regression (1) in table 3, both $Cons_{EU,t-3}$ and $Ind_{BRICS,t-3}$ are significant, at the 5% and 1% levels respectively . Hence, we verify that indicators of local and foreign demand carry explanatory power in cement net imports. Indeed, an increase in local demand is expected to increase the demand

[17]For simplicity we do not display the values of the constant term and the ARIMA terms. More detailed results are available upon request

of imports and reduce production capacities available for exports[18]. In our model, an increase of 10 points in local demand [19] would induce an increase of about 3 million tonnes of net imports. Moreover, we notice that the signs of the estimated coefficients of $Cons_{EU,t-3}$ and $Ind_{BRICS,t-3}$ conform to the theoretical model (equation (6)). The Ljung-Box-Pierce test validates that the residuals of regression (1) are not autocorrelated.

The coefficients of $Cons_{EU,t-3}$ and $Ind_{BRICS,t-3}$ in regression (2) are very similar to the coefficients of regression (1), and statistically significant at the 10% and 5% levels respectively. This similarity indicates that the relationship between the cement net imports and local and foreign demand is robust. CO_2price_{t-3} is not statistically significant : the carbon price has no impact on the cement net import variations. The results of (1)bis and (2)bis in table 4 are close to the results of (1) and (2), which is reassuring for the robustness of the results. The coefficients, except for the carbon price, are all significant at the 1% level.

For steel (regression (3) in table 5), $Ind_{EU,t-3}$ is significant at the 1% level, but $Ind_{BRICS,t-3}$ is not statistically significant, whereas in (3)bis they are both significant at the 1% level. Only the local demand carries explanatory power in the ARIMA model, while both local and foreign demands do so in the Prais-Winsten estimation. The impact of the local demand is bigger in the steel industry than in the cement industry[20] compared to the cement net imports: an increase of 10 points in local demand would lead to an increase of about 9 million tonnes in net imports. As for cement, the similarity between the results of the two periods implies that the relationship between the steel net imports, local and foreign demand is robust. Similarly to the cement industry, the coefficient of the carbon price CO_2price_{t-3} is not statistically significant.

6. Discussion

The relationship between net imports and European or foreign demand that was predicted by the analytic model is confirmed by the empirical analysis. An increase in local (respectively foreign) demand increases (respectively decreases) net imports. The fit is particularly good for the cement industry and a little less so for the steel industry.

Furthermore, our empirical model does not support the hypothesis that a high carbon price would induce an increase in net imports. For cement and steel, the coefficient of the carbon price has no explanatory power on net imports, even

[18]When carrying Prais-Winsten regressions for imports and exports separately instead of just net imports (results available upon request), we observe that the signs of the demand coefficients still conform to predictions. An increase in local demand induces an increase of imports and a decrease of exports (and the other way around for foreign demand).

[19]The demand was normalized at 100 in 2005

[20]The approximate size of cement net imports are a bit more than half as large as steel net imports (see Table 2), but the estimated coefficient for local demand (approximated by EU construction or industrial indexes, both around 100) is three times larger

Table 3: Regression estimations. Cement Net Import. ARIMA regressions

Cement $NImp_{Cement,t}$	1999-2012 (1)	2004-2012 (2)
$Cons_{EU,t-3}$	0.298	0.326
	(2.39)**	(2.38)**
$Ind_{BRICS,t-3}$	-0.344	-0.344
	(3.45)***	(3.08)***
CO_2price_{t-3}		-0.093
		(0.51)
N	164	104
Loglikelihood	-387.06	-242.98
AIC	798.12	511.95
BIC	835.32	546.33
Q	28.57	23.41
Prob>chi(40)	0.91	0.98

Table 4: Regression estimations. Cement Net Import. Prais-Winsten regressions

Cement $NImp_{Cement,t}$	1999-2012 (1) bis	2004-2012 (2) bis
$Cons_{EU,t-3}$	0.580	0.469
	(5.70)***	(4.08)***
$Ind_{BRICS,t-3}$	-0.100	-0.200
	(4.56)***	(5.77)***
CO_2price_{t-3}		0.036
		(0.33)
N	165	105
Adjusted R^2	0.27	0.48
R^2	0.25	0.44
ρ	0.71	0.69
DW (original)	0.75	0.75
DW (transformed)	2.34	2.19

Table 5: Regression estimations. Steel Net Imports. ARIMA regression

$NImp_{Steel,t}$	1999-2012	2004-2012
	(3)	(4)
$Ind_{EU,t-3}$	1.025	1.253
	(3.15)***	(3.08)***
$Ind_{BRICS,t-3}$	0.117	0.015
	(0.60)	(0.06)
CO_2price_{t-3}		0.103
		(0.46)
N	164	104
Loglikelihood	-501.15	-325.88
AIC	1022.29	675.77
BIC	1053.29	707.50
Q	51.83	30.41
Prob>chi(40)	0.10	0.86

Table 6: Regression estimations. Steel Net Import. Prais-Winsten regressions

Steel	1999-2012	2004-2012
$NImp_{Steel,t}$	(3) bis	(4) bis
$Ind_{EU,t-3}$	1.411	1.480
	(4.81)***	(4.20)***
$Ind_{BRICS,t-3}$	-0.184	-0.257
	(3.38)***	(3.14)***
CO_2price_{t-3}		0.129
		(0.50)
N	165	105
Adjusted R^2	0.13	0.21
R^2	0.14	0.23
ρ	0.76	0.74
DW (original)	0.54	0.56
DW (transformed)	2.09	2.04

though the CO_2 price has exceeded 20 euros for more than two years during the studied period. Although based on a longer time series and more elaborate econometric techniques, this empirical work draws the same conclusion as the previous empirical literature on carbon leakage and the EU ETS (Reinaud, 2008a; Lacombe, 2008; Sartor, 2013; Ellerman et al., 2010; Quirion, 2011). That is, the adverse effects of the EU ETS on EITE industries promised by their trade bodies (EAEII, 2010) have not been observed. Nevertheless, these sectors have benefited from a generous free allocation of allowances due to member states at first and economic recession afterwards (Branger et al., 2013). We cannot draw a conclusion about the role of this free allocation in the absence of leakage.

In addition, our analysis considers only changes in the use of production capacities (operational leakage) in the short term, which could be due to market share loss to foreign competitors, or to an optimization strategy of a globalized firm. It does not take into account changes in production capacities as the result of the EU's climate policy (investment leakage), which could be investigated through foreign direct investment data (as in the original pollution haven literature).

At the end of 2014, the mid-term review of the European Commission will reevaluate the methods of allocation, especially for sectors deemed to be exposed to carbon leakage. Assumptions underlying the first evaluation in 2009 need to be updated (De Bruyn et al., 2013). First, carbon prices are much lower than those used for the elaboration of allowances rules (30 euros per tonne), and so are additional carbon costs. Second, the EU ETS is linked with more countries (Norway and Iceland joined the EU ETS) and other carbon markets are emerging in several states (some of which are located in the first two emitting countries, the US and China). This would lower the intensity of international competition and would offset the growing integration of markets (especially in the steel sector).

The exceptional growth of industrial activities in emerging countries and the deindustrialisation of Europe are long-term trends. As it is impossible to know what would have happened if the EU ETS had not existed (the "plague of the counterfactual scenario" (Reinaud, 2008b)), environmental regulations could be held responsible for what is actually a structural change. European heavy industries would then put the blame on the EU ETS to ask for unjustified help, as their trade associations have been actively lobbying to undermine reforms that would raise the environmental ambition of the EU ETS. The fear of competitiveness and carbon leakage have led to generous free allocations, which caused a surplus of allowances and the crash of their price, threatening the very existence of the scheme. The collapse of the carbon price is a very serious issue, as a 5 euro allowance price does not send the right signal in regards to investing in low-carbon facilities. The future of European industry lies in technological innovation and high-value-added products, which could be helped by a strong price signal.

Table 7: Augmented Dickey-Fuller (ADF) tests for unit root

	1999-2012		2004-2012	
	Test Statistic	p_value	Test Statistic	p_value
$NImp_{Cement}$	-2.527	0.1091	-1.578	0.4947
$\triangle NImp_{Cement}$	-18.849	0.0000	-14.275	0.0000
$NImp_{Steel}$	-2.881	0.0477	-2.013	0.2807
$\triangle NImp_{Steel}$	-14.655	0.0000	-11.296	0.0000
Ind_{EU}	-1.709	0.4266	-1.137	0.6999
$\triangle Ind_{EU}$	-11.065	0.0000	-7.683	0.0000
Ind_{BRICS}	0.730	0.9904	-0.636	0.8627
$\triangle Ind_{BRICS}$	-17.279	0.0000	-13.692	0.0000
$Cons_{EU}$	-1.425	0.5702	-0.770	0.8277
$\triangle Cons_{EU}$	-18.429	0.0000	-14.566	0.0000
CO_2price			-2.094	0.2471
$\triangle CO_2price$			-8.518	0.0000

The ADF model specified is model with constant

7. Annex

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